AUTOMATIC DESIGN OF MAIN PEDESTRIAN ENTRANCE OF BUILDING SITE BASED ON MACHINE LEARNING

A Case Study of Museums in China’s Urban Environment

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Abstract. The main pedestrian entrance of the building site has a direct influence on the use of the buildings, so the selection of the main pedestrian entrance is very important in the process of architectural design. The correct selection of the main pedestrian entrance of building site depends on the experience of designers and environment data collected by designers, the process is time consuming and inefficient, especially when the building site located in complex urban environment. In order to improve the efficiency of design process, we used online map to collect museums information in China as training samples, and constructing artificial neural networks to predict the direction of the main pedestrian entrance. After the training, we get the prediction model with 79% prediction accuracy. Although the accuracy still need to be improved, it creates a new approach to analysis the main pedestrian entrance of the site and worth further researching.

Keywords. Artificial Neural Network (ANN); Main Pedestrian Entrance of Building Site; Automatic Design.

1. INTRODUCTION

In China’s contemporary urban environment, the main vehicle entrance of building site is easy to determine according to laws, regulations or urban planning. However, designers are always difficult to make the choice for the main pedestrian entrance of building site in a short time, as the location of main pedestrian entrance is affected by many factors, such as roads, public transportation sites and urban public spaces. Sometimes, in order to get the correct choice of the main pedestrian entrance of the building site, on-site research and questionnaires are also needed, which makes the design process become more complex and inefficiency. With the help of automatic design and computer technology, the design process can be simplified and the efficiency can be improved. However, the generation rules of
traditional automatic design are often set by one designer or a group designers, with a strong sense of subjectivity and bad performance. With the help of the Artificial Neural Network (ANN), the performance of automatic design can be improved. The underlying relations between input and output variables as well as interactions between input variables artificial can be analysed by neural network (Saraee et al, 2011), avoiding the drawbacks of setting generation rules subjectively, and having a better performance than the traditional automatic design.

This article has two purposes. Firstly, the artificial neural network is trained by the collected dataset to obtain a prediction model with the highest accuracy of prediction of the main pedestrian entrance of building site in urban environment of China. Secondly, the prediction model will be used under the Rhinoceros and Grasshopper environment to verify the accuracy of the prediction in real design process.

This paper chooses modern museums in the urban environment as the research object, as museums in the city usually has an independent main pedestrian entrance, which are suitable for this research. By collecting the surrounding information of the established museum as input data, and the information of the main pedestrian entrance of the site of museums as output data, the artificial neural network prediction model will be trained. The prediction accuracy increased after the artificial neural network had been trained by different types of input data.

In this paper, artificial neural networks are used to optimize the design process, a number of related precedents have used the neural network to do some other researches in architecture. Such as training the robotic with artificial neural networks to achieve the effect of artificial carving (Giulio et al, 2017), the use of artificial neural networks to predict wind pressure in high-rise buildings (Wilkinson et al, 2014), Using neural networks to control the dynamic shading system to create the best indoor lighting conditions (Nabil et al, 2014), and using the artificial neural network to predict the energy consumption of buildings (Ekici et al, 2009).

2. METHODS

This research is divided into four parts, establishing dataset frame, collecting dataset, training artificial neural network, and realizing prediction model in Rhinoceros and Grasshopper (Figure 1).

![Figure 1. The training methods are structured and evaluated in three main stages: Collecting, Learning, Using.](image-url)
The first step of establishing the dataset framework is to set the criteria to select the museums that meet the research requirements. The shape of the building site of museums varies, such as round, oval, rectangular, square, polygon, etc. To simplify the problem, in this paper we mainly choose the museums with rectangular or square building site (the most common building site shape in architectural design) as research sample, we will take more complicated shapes, like polygon and arcs, into consideration in the later research, and the research object of this study is the museums in urban environment which were built in the modern times, so all museums in china are filtered by the following criteria:

- Museum should with a rectangular or square building site
- Museum should be located in cities rather than villages
- Museum and urban environments should be directly linked with urban roads
- Museum should be independent and not affiliated with other buildings.
- Museum should be new, not rebuilt from old buildings

The second step in establishing the dataset framework is to choose the input data to train the artificial neural network. Firstly, the roads information around the site needs to be collected. Roads are the main way of connecting the site and the city, having a great influence on the choosing of the main pedestrian entrance of the site. The road information will be recorded according to four directions: north, south, east and west. Secondly, the public transportation sites information around the site also needs to be collected, public transportation sites can bring a large number of people in a short time, and then affect the main flow of people as well as the choosing of main pedestrian entrance of the site. In cities, Public transportation sites include bus stations and subway stations. The influence of public transportation sites depends on three aspects: the number of buses or subways stop in the public transportation site, the distance between the public transportation site and the building site, and the direction of the public transportation site relative to the building site. Finally, the city public spaces, such as parks and squares, are also important to choosing the correct main pedestrian entrance of building site, for example, when a museum has a park or a square nearby, the main pedestrian entrance direction will always tend to the park or the square. In conclusion, the input data contains three aspects, the roads information, the public transportation information and the public spaces information.

The final step of establishing the dataset frame is to confirm the output data of the artificial neural network, the output data is the direction of main pedestrian entrance of museum sites. The output data has four kinds of possibility: east, south, west, and north.
After the dataset framework (Figure 2) has established, the next step is to collect the data.

Firstly, all museums are filtered with the criteria set previously. According to the latest list of all museums in China “2015 National Museum Directory of China”, published by the State Administration of Cultural Heritage of China, China currently has a total of 4,626 museums, these museums are divided into four categories (The First Class Museum, The Second Class Museum, The Third Class Museum, The Classless Museum). The first three types of museums usually have an independent main pedestrian entrance, and always located in the urban environment, more likely to meet the research requirements, the first three categories have a total number of 724 museums, 269 of them meet the criteria set previously. In order to make the dataset more comprehensive and rich, 171 classless museums are randomly selected to join the dataset. As a result, the dataset consists of 440 museums in total.

The next step is to obtain the road information, public transportation sites information and urban public spaces information of each museums. In the access of road information, the level and the width are the most important information, the OpenStreetMap is mainly used in this period. OpenStreetMap provides detailed road information and divides the roads into 8 different levels (motorway, trunk, primary, secondary, tertiary, unclassified, residential, service). Therefore the level of any road can be described as a number of 1 to 8, the smaller the number, the higher the road level. The lanes of the road is described by the number of roads shown in the map.

The method of getting public transportation sites information and urban public spaces information are basically the same, mainly through the Web Services API provided by Baidu Map (one of the most popular online maps in China, which contains richer information and updates faster than Google Maps in China). The Web Service API of Baidu Map provides a series of interfaces, which can initiate
retrieval request via HTTPS form, get retrieval data in JSON or XML format, this article mainly uses the “location retrieval service”, “forward/reverse geocoding service” and “batch calculation Road service” in Web Services API of Baidu Map. Firstly, the name of a museum and its specific address obtained according to the file “2015 National Museum Directory of China”. Secondly, the longitude and latitude coordinates of the museum are obtained by “forward/reverse geocoding services” through the name of the museum and the specific address. Next, searching Bus Stations, Subway stations, Squares, and Parks through the “Location Retrieval service” in the range of 1 kilometer, with the museum as the center point. The return data includes the “Name”, “Address”, “Latitude and longitude coordinates” of the bus stations, subways stations, parks and squares. In step fourth, the information of how many buses or subways stop in the public transportation site can get from “Address” information in the return data directly. Then, through the “Bulk calculation Road Service”, the distance of bus stations, subway stations and urban public spaces can be obtained. “Bulk computing Road service” can calculate the distance of two points through the latitude and longitude coordinates. Finally, we calculate the direction of public transport site and city public space relative to the museum through the latitude and longitude coordinates, the direction is recorded as zero when the public transportation sites or the public spaces are north of the museum, and angle increases in the clockwise direction. All input data collected through the above steps.

The last step of collecting data is to obtain the output data , the location of the main pedestrian entrance of each museum site. This step mainly completed by observing the satellite map and the street view map to judge the main pedestrian entrance of a museum. Through the satellite map we can always see the museum entrance square, and through the street view map we can see the museum’s main facade, based on these two points we can judge the main pedestrian entrance position of the museum. The output data recorded as east, or south, or west, or north. The Figure 3 shows the input and output data extracted from a museum (the museum of Hebei province, China) in the dataset.
The artificial neural network in this paper based on reverse propagation algorithm, and has three layers, output layer (first layer), hidden layer (second layer) and output layer (third layer). The artificial neural network takes the road information, the public transportation sites information and the urban public spaces information as the input data, and the output data is the position of the main pedestrian entrance of the museum. The whole dataset are randomly divided into training sets and test sets (80% and 20%), training sets are used to train artificial neural network prediction model, and test sets are used to test the prediction accuracy of artificial neural network.

After the training completed, Rhinoceros and Grasshopper are used to utilize the prediction model. First, by drawing or importing CAD files to get the site plan in Rhinoceros, and then use the Grasshopper to get input information, including the building site boundary, the location of the public transportation sites as well as the location of city public Spaces. These information will then be converted into data that can be identified by the artificial neural network., and prediction result then displaying on the screen.

3. RESULTS
The results of this study include two parts, the accuracy of prediction model after trained and the accuracy of prediction model in the real design process.

Firstly, the artificial neural network is trained by different types of input data to find the prediction model that with the highest prediction accuracy. When only one type of data is used as the input data to train the prediction model,
the prediction accuracy of model trained by the road information is the highest, followed by the public transportation sites information, and then the urban public spaces information, respectively 65%, 30%, and 20% (figure 2). Because of the good performance of the road information, the second training carried out by combining road information with other information, the results show that the accuracy of all models are improved. The biggest improvement shows in the combination of road information and public transportation sites information, reached 79%, others also have a small increase, but are less than 79% (figure 3). After training prediction models in different types of input data, we found that the best predictive model is the model that using the roads information and public transportation sites information as the input data.

Figure 4. Predicted Values and Actual Values (trained by one kind of input data, blue points are correct prediction valves, yellow points are wrong prediction values).

Figure 5. Predicted Values and Actual Values (trained by multiple kinds of input data, red points are correct prediction valves, green points are wrong prediction values).

We also want to verify the performance of the prediction model in the actual design process, we have designed 10 different site plans (figure 4), and invited three postgraduate students with five years of design experience to participate in the experiment, the experiment was carried out three times, each time by a graduate student and the artificial neural network prediction model participates in, the experiment content is choosing the direction of the main pedestrian entrance of
the building site in 10 site plans. The experimental results show that the similarities of the result of prediction model and three postgraduate students are 80%, 70% and 90% (figure 5).

Figure 6. Ten Site Plans.

Figure 7. The Comparison of Prediction Result of Postgraduate Students and ANN.

4. CONCLUSION

Through the above experiments, we found that the road information and public transportation sites information around the site have the greatest impact on the choosing of the main pedestrian entrance, selecting these two as input data to train the artificial neural network can get higher prediction accuracy.

In future studies, the accuracy of the model can be further improved by improving the following aspects. The first thing is to collect more data samples, in the area of image recognition and voice recognition, the prediction accuracy of neural network is beyond the human, these neural networks based on ten thousands of samples, or even millions of training data samples, this article currently uses only 440 data samples. therefore, expanding the number of data samples will contribute to a significant increase in prediction accuracy. Secondly, the prediction accuracy and the extraction of feature factors are closely related, this paper mainly extracts the roads information, public transportation sites information, urban public spaces (parks, squares) information as a characteristic factor, if more influence factor can be extracted, the prediction accuracy will obtain the further
promotion.

References